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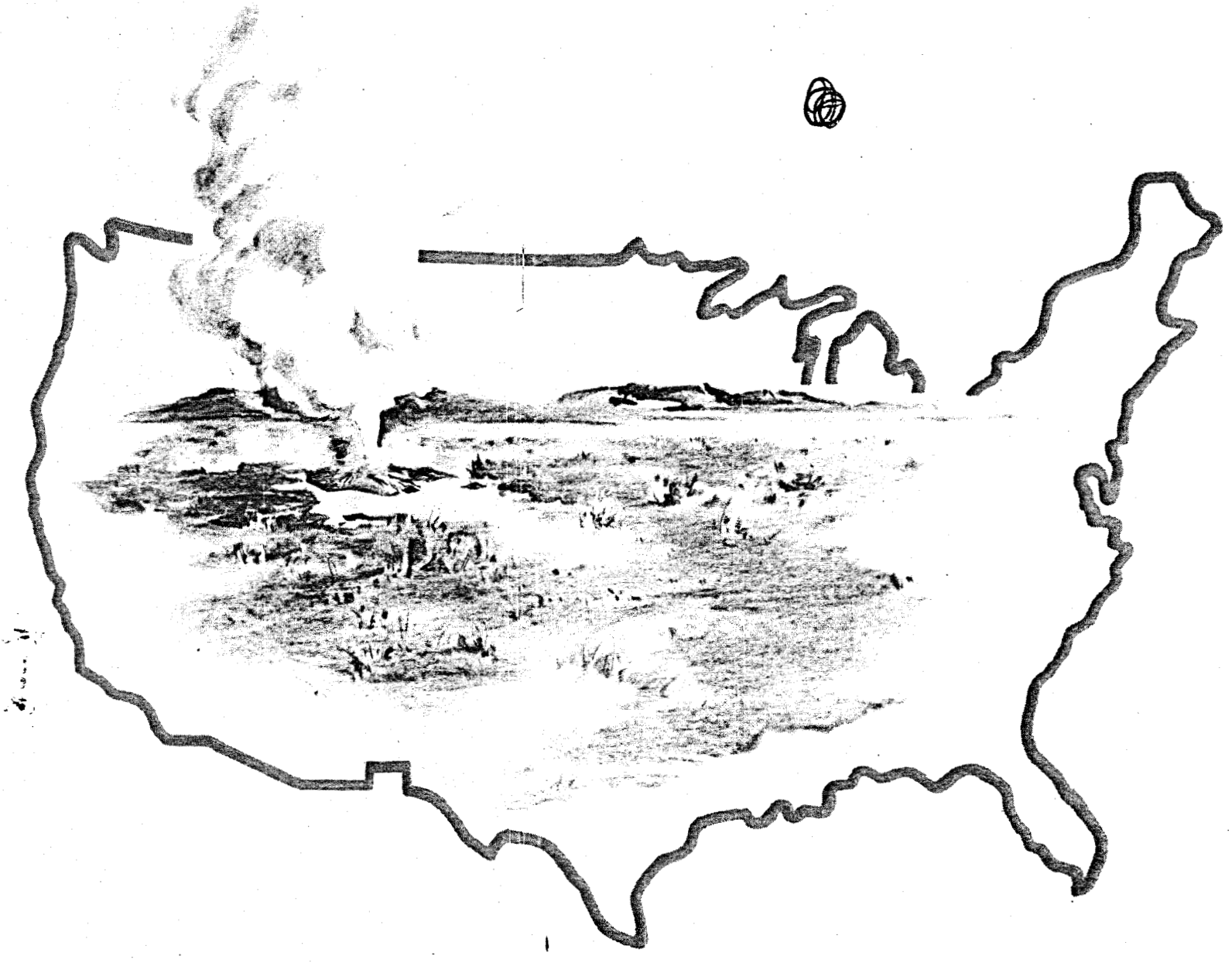
Geothermal Programs

Idaho Operations Office

Low-to-Moderate Temperature Hydrothermal Reservoir Engineering Program Plan



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PROGRAM PLAN

LOW-TO-MODERATE TEMPERATURE HYDROTHERMAL RESERVOIR ENGINEERING

OBJECTIVE

The objective of this program is to assure that appropriate methods of reservoir testing and analysis are available to facilitate the development and utilization of low-to-moderate temperature (<150°C) hydrothermal resources by private industry.

SUMMARY

A major impediment to the commercialization of low-to-moderate temperature hydrothermal resources is the lack of confidence that the reservoir is adequately large and that it will satisfactorily produce during the life of the project. These resources cannot generally be developed for economic electrical generation; most will be developed for small-scale, direct heat applications. To increase reservoir confidence, there is a need for low cost methods for the prediction of long-term reservoir performance. The high permeabilities, lower pressures and low heat content of these resources make much of the technology developed for high temperature reservoirs inappropriate or unnecessarily expensive when applied to single phase systems. Frequently, modified groundwater analysis techniques are more applicable. This program will develop cost-effective reservoir testing and analysis methods that can be readily applied to low-to-moderate temperature reservoirs. The program will aid and accelerate the development of the known low-to-moderate temperature hydrothermal resources in the United States. Development of energy associated with these resources (72% of the total identified) has the potential to offset 6×10^{13} barrels of oil (USGS Circular 790).

The program will consist of the following elements:

1. Program Review/Strategy
   - Case Studies
   - Industry Evaluation
   - Program Definition/Management
2. Testing and Analysis
   - Testing Methodology
   - Instrumentation
   - Single-phase Testing Analysis/Prediction
   - Production Data Analysis
3. Fluid Disposal
   - Project Experience
   - Guidelines
4. Technology Transfer
   - Handbook
   - Technical Assistance
   - Training Programs

SCHEDULE

The summary schedule for the program is shown in Figure 1. The first phase of the program will concentrate on reviewing the experience from existing projects, developing test methodology, and developing a technical assistance program. The development, revision, and improvement of analysis methods will be based on the requirements identified in the early part of the program.

BUDGET

The cost breakdown for each of the elements included in the program is shown in Table 1.

DISCUSSION

1. Program Review/Strategy

The objectives of this program element are to review the experience gained in low-to-moderate temperature reservoir development projects and to define the areas where reservoir engineering related problems occurred. The tasks which are included to meet this objective are discussed below.

1.1 Case Studies

Case studies will be prepared for a few privately-developed projects and for projects under the PON, Industry-Coupled, Loan Guarantee and User-Coupled Confirmation Drilling programs. These case studies will include a review of the resource information available at the beginning of the project, including exploration efforts, the initial assumptions about the resource, the methods used for resource evaluation and reservoir testing, and the technical and economic decisions made which affected the results of the project. Emphasis will be placed on the reservoir assessment techniques used and the comparison of predictions with actual production data. The success or failure of each project will be analyzed to determine the lessons learned. On the basis of these projects, recommended strategies for resource development and reservoir testing will be identified. Follow-on verification of these recommendations will be made through tracking of future resource development projects. Project files and case studies will be maintained and made available to regional labs, State teams, consultants, developers, and the business and financial community.

Deliverables

- Case Study Reports

1.2 Industry Evaluation

This task will evaluate the experience and understanding of resource development and testing techniques in the private sector. This evaluation will be accomplished by 1) reviewing testing and analysis programs included in resource development proposals, and 2) contacting resource developers and analysts to determine what problems they see in

the state-of-the-art of low and moderate temperature reservoir engineering. A summary of the status of industry expertise and industry needs will be prepared.

Deliverables

- Report on the status of industry capability

1.3 Program Definition/Management

The assessment of the status of reservoir engineering technology and technology development requirements identified in the case studies and industry evaulation will be used to determine the direction of subsequent reservoir engineering programs. The Testing and Analysis and Technology Transfer elements of the program as a whole will include input from the Program Review to reflect the status of industry. Large-scale integrated resource analysis techniques will be evaluated and the feasibility of promoting reservoir management concepts for total energy resource development will be determined. An informal industry advisory panel will be formed to aid in the program review.

Deliverables

- Revised program plan and recommendations

2. Testing and Analysis

Well testing and well test analysis in low-to-moderate temperature geothermal resources are often complicated by non-isothermal, temperature dependent, pressure behavior. If this behavior is not correctly interpreted, erroneous conclusions about reservoir properties and geometry, and thus resource productivity, will be obtained. Unlike groundwater aquifer exploitation and petroleum reservoir exploitation, single-phase geothermal reservoirs have two important production fluid characteristics: fluid volume and fluid temperature. While we can make predictions, with a good degree of confidence, of long-term pressure drawdown, and thus production volume, to date there is little methodology developed to predict thermal decline of the produced fluids in low-to-moderate temperature hydrothermal resources.

2.1 Testing Methodology

Test methodology and analysis techniques for pressure and thermal decline will be investigated and evaluated. Methods from the water well and petroleum industry will reviewed for their applicability to testing of low-to-moderate temperature reservoirs. Well test methods, specific to these systems, will be developed so that long-term pressure and thermal behavior can be predicted from pressure transient production and interference testing. This information will be made available by means of the handbook and training courses for industry, developers, consultants and State teams (see 4.0).

Deliverables

- Report on testing methodology

2.2 Instrumentation

State-of-the-art instrumentation to measure temperature, pressure, water level and flow will be researched. Off-the-shelf instrumentation and measurement components, applicable to geothermal well testing and reservoir monitoring, will be identified. Testing and evaluation of the components and/or instrumentation will be performed in cooperation with manufacturers and users. Those components identified as suitable for low-to-moderate temperature geothermal application will be packaged for use in well testing and reservoir monitoring. These combined instrumentation packages will be tested in various DOE-sponsored reservoir development programs. Once satisfactory designs have been obtained, drawings will be made available to industry and/or manufacturers.

Deliverables

- Report on available instrumentation and components
- Prototypes for geothermal testing using off-the-shelf components

2.3 Single Phase Testing Analysis/Prediction

Existing computer codes for modeling hydrothermal systems will be used to determine optimal strategy for well testing, development, and reservoir management in a variety of typical low-to-moderate temperature reservoir systems. Pressure and thermal behavior, in response

to reservoir utilization will be investigated. Difficulties in using these computer codes for typical low and moderate temperature systems will be identified. Streamlined, user-oriented versions of these codes will be developed for use by developers, industry, consultants, etc. Programs for microprocessors and programmable calculators will be developed for the evaluation of hydrothermal reservoir engineering data. These will include methods for analyzing interference tests and tests in fractured or otherwise anisotropic conditions. Technical assistance will be available for demonstrating how to use these codes and to run site-specific calculations as part of 4.2, Technical Assistance.

Deliverables

- Input to Handbook on well testing and analysis methods
- Computer codes for hydrothermal reservoir calculations
- Programs on floppy discs or mag cards and users guide for reservoir data analysis and graphic output

2.4 Production Data Analysis

Methods for dealing with data collected during long-term operation of a wellfield or an individual well will be investigated. Types of systems such as fractured, sedimentary or combination will be identified. Long-term predictions of temperature and pressure will be made using different methods for each type of system and compared to each other. Transient test data will be used to develop and compare predictive methods. Codes modified in Task 2.3 and decline curve methods will be used for evaluating long-term predictions.

Deliverables

- Report on collection and analysis of data from producing wellfields
- Comparison of long-term predictive methods

3. Fluid Disposal

This task will result in an evaluation of various fluid disposal methods and their viability. Particular attention will be given to disposal by injection and the technical, regulatory, and environmental considerations for its use.

3.1 Project Experience

Case histories of hydrothermal fluid disposal systems from hydrothermal development projects will be written. Methods of disposal will be compared and evaluated with respect to cost, efficiency of energy recovery, regulatory problems, effect on water rights considerations and technical feasibility. Systems where injection is the disposal method used will be emphasized for technical problems such as well design, interference with production wells and cost effectiveness.

Deliverables

- Report on fluid disposal case histories

3.2 Guidelines

A generalized decision path flow chart will be made to aid developers in choosing a disposal method. A separate flow chart for planning an injection disposal system will be included. The technical problems of injection well location and depth, design and drilling, choice of disposal zone, effect of injection on the pressures and temperatures of the geothermal resource, operation and maintenance of the injection system, injection well clogging and its prevention will be addressed. An existing numerical simulation of injection well clogging will be modified to handle geothermal fluid injection. The results of running this model for some typical cases can be used to determine the extent of pretreatment necessary and the longevity of the injection system. Economic considerations in the design of a geothermal injection well system will be discussed.

Deliverables

- Decision analysis for disposal methods and injection system planning
- Predictive model of injection well clogging
- Report on technical problems and solutions for injection systems

4. Technology Transfer

The objective of this program element is to develop, synthesize and transfer the reservoir engineering technology developed by DOE to private industry. As this program progresses and industry establishes its skills

in low-to-moderate temperature reservoir engineering techniques, DOE's involvement will be phased out.

4.1 Handbook

A handbook on well testing and analysis will be prepared for use by developers and consultants. The handbook will include guidelines for planning well tests in typical hot water hydrothermal systems, sample well test plans for various situations, discussions of well test data analyses, analytical methods most commonly used and their limitations, and microcomputer and calculator programs for analyzing well test data. The methods for the economic assessment of reservoirs will be included. As instrumentation, testing, and analysis methods are developed (see 2.0, Testing and Analysis), the handbook will be revised to include these methods. Periodic conferences will be held to aid in updating and acquiring industry input for the handbook.

Deliverables

- Testing and analysis handbook (updated)

4.2 Technical Assistance

A "100 hours" reservoir engineering and geochemical technical assistance program will be initiated and maintained at INEL and LBL. Personnel will also work with UURI, Gruy-Federal and OIT on User Assistance requests. The initial phase of the program will include the establishment of ground rules, program advertisement, and the assessment of regional needs and capabilities. To facilitate technology transfer and to reduce the potential for conflict of interest, industry consultants will be included as much as possible in the program. Included in the available technical assistance will be geochemical techniques, test planning, test analysis techniques and assistance in the use of computer models.

In conjunction with this program, an equipment loan program will be developed. Sophisticated well testing equipment that is generally too expensive for individual developers to purchase will be made available for individual well tests. Equipment for measuring pressure, temperature and flow rate for standard well completion and piping arrangements will be included. Trained personnel will be loaned with the equipment to provide

technical assistance. The equipment will be made generally available to facilitate technology transfer and training.

Deliverables

- Establish Technical Assistance programs
- Establish equipment loan depots

4.3 Training Programs

A reservoir testing and analysis training program for State teams, consultants and developers will be established. The training program will address well tests and how they are conducted, working within field constraints, the applicability and effectiveness of instrumentation, and analytical techniques, their data requirements and their restrictions. The training will include classroom instruction utilizing actual project data and "hands-on" field testing.

Deliverables

- Conduct of training sessions.

1. Program Review/Strategy
   - Case Studies
   - Industry Evaluation
   - Program Def./Mgmt.

2. Testing and Analysis
   - Testing Methodology
   - Instrumentation
   - Single-ph. Testing
   - Prodn. Data Analysis

3. Fluid Disposal
   - Project Experience
   - Guidelines

4. Technology Transfer
   - Handbook
   - Tech. Assistance
   - Training Programs

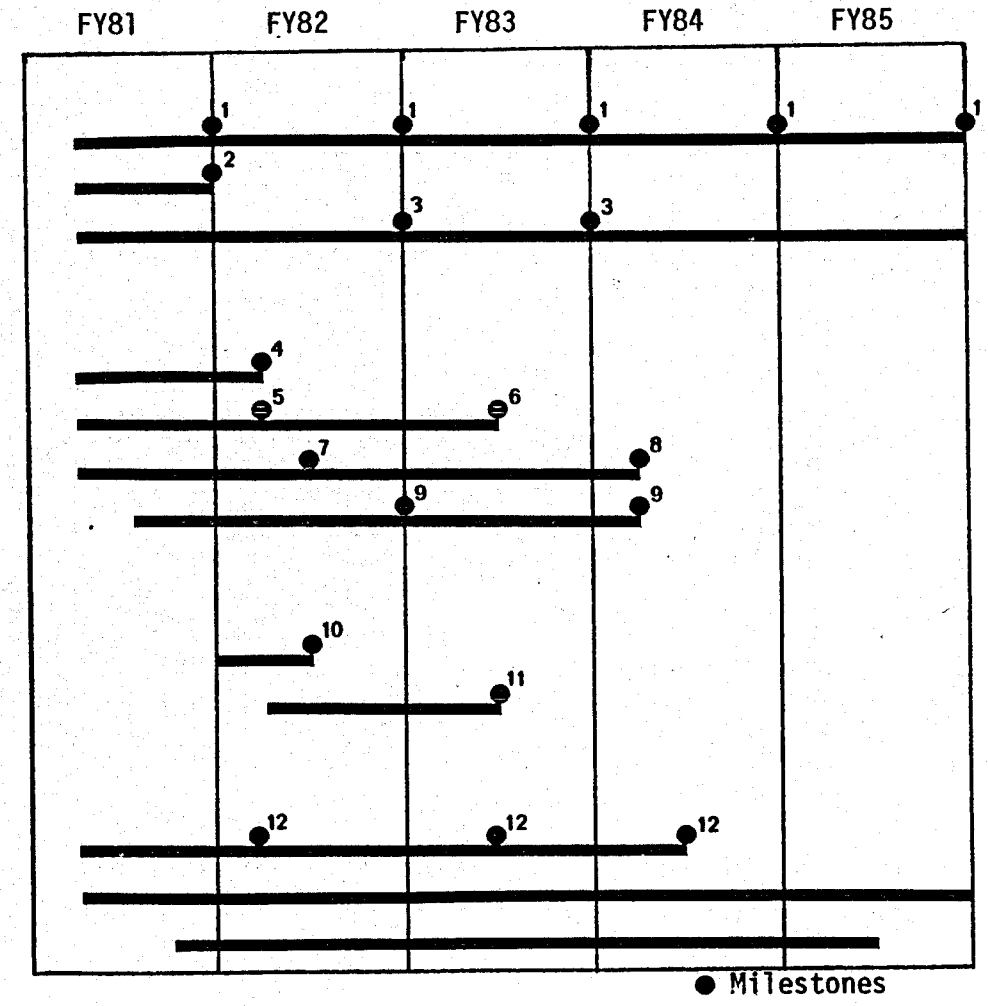

FIGURE 1. PROGRAM SCHEDULE

MILESTONES

1. Issue Case Study reports
2. Report on status of industry capability
3. Issue revised program plan and recommendations
4. Complete report on testing methodology
5. Issue report on available instrumentation
6. Complete prototypes for instrumentation
7. Issue report on reservoir analysis techniques
8. Issue users guides for single-phase and microcomputer programs
9. Issue report on production data collection and analysis
10. Issue fluid disposal case histories
11. Issue fluid disposal guidelines
12. Issue testing and analysis handbook (revisions)

TABLE 1

BUDGET
($000)

	FY-81	FY-82	FY-83	FY-84	FY-85
1. Program Review					
• Case Studies	30	60	60	60	60
• Industry Evaluation	20				
• Program Definition/ Management	15	45	40	25	15
Subtotal	65	105	100	85	75
2. Testing and Analysis					
• Testing Methodology	20	20			
• Instrumentation	35	60	30		
• Single-phase Testing Analysis/Prediction	20	80	80	40	
• Production Data Analysis	20	40	40	20	
Subtotal	95	200	150	60	
3. Fluid Disposal					
• Project Experience		30			
• Guidelines		40	40		
Subtotal		70	40		
4. Technology Transfer					
• Handbook	35	80	30	20	
• Technical Assistance	40	70	150	70	50
• Training Programs	15	25	50	25	15
Subtotal	90	175	230	115	65
TOTAL	250	550	520	260	140